Can a new materials innovation in thin film optical applications be faster and cheaper?

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Contents

• Introduction:
  – New materials innovation is important for optical applications
  – Materials development is complex and time consuming
• How to enhance the materials research?
  – Current technologies for materials research
  – What can further enhance innovation?
• Case studies
• Summary
New materials innovation is important for optical applications

• Cell phone glass coating:
  – Anti-finger print
  – Anti-reflection, anti-glare
  – Anti-scratch …. 

• New features for display glass coating

• Wearable display products

• Solar panels

• Others…..
Materials development is complex and time consuming

- Materials development is time consuming
  - It could be 10-20 years from lab discovery to first practical use
- Lab materials screening is complex and time consuming

Example of time frame for bringing new materials to market

**ACS Comb. Sci. 2011, 13, 579–633**
What can we do?

• Moore’s law predicts faster, cheaper, more powerful solutions in the future

Moore’s law

![Graph showing the decrease in the average price of a transistor from 1968 to 2004.](image-url)
Current Technologies for Materials Research

- Combinatorial is a common technology for materials research

Combinatorial insights into doping control and transport properties of zinc tin nitride


[www.win.tue.nl/~adibucch/2DS01/2DS01lec5.ppt](http://www.win.tue.nl/~adibucch/2DS01/2DS01lec5.ppt) Statistics 2 for Chemical Engineering. lecture 5.

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What can further enhance materials innovation?

• “The more brains, the better”
• How can attract more brains (more people) on innovation?
• Can materials innovations be accessible, affordable, and open to more brains (more people)?
• Reducing the threshold on the innovation is a way to attract more brains,
  – Hardware
  – Software
  – Knowledge barrier

cims.ncsu.edu/the-more-brains-the-better/
Can research project threshold be significantly reduced?

• Traditional research project needs
  – PhD lead
  – Millions $ findings
  – Well prepared plan, and complicated funding application procedures

• Could new optical coating prototypes, publications for a project cost at
  – 100 time cheaper?
  – 10-100 time faster?
  – At $10,000 scale?

• Don’t need ten year training as a PhD?
Affordable equipment (Moore’s law)

- Ten Million $ equipment will limit most people from the research
- Combinatorial sputter deposition equipment
  - High quality
  - High throughput

What if Reduce cost 100 times?

http://www.semicat.com/about_us

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High quality thin Film Research PVD

- High quality sputter deposition
  - Background vacuum $9 \times 10^{-8}$ Torr
  - Independent three Pulsed DC sputtering

- Friendly operation interface
  - Automatic run with programmed recipe
  - Experimental parameters can be monitored and recorded.

**Sputtering voltage monitoring (V)**

- Voltage 2
- Voltage 1

**ion Gauge (in Pa, or 1/133 Torr)**

- ion Gauge

$3.8 \times 10^{-5}$ Pa = $2.2 \times 10^{-7}$ Torr
High Quality Extensive New Materials Research Capability

- Capability to co-sputter and deposit stacks
  - Metals
  - Alloys
  - Metal nitrides
  - Metal oxides

Workable elements
Affordable high quality characterization facilities

- World class metrology available on-site:
  - **Spectroscopic Ellipsometry**
    - Refractive index n, k, as well as film gradient
    - Single layer films / multiple layers stacks
  - **Optical UV-VIS-IR spectra (200nm-2500nm)**
    - Transmission, reflection and absorption
  - **Unique Optical Reverse Engineering and Software**
  - **Electrical Sheet Resistance, Carrier density and mobility**
  - **More characterization available on site with a partner**
    - AFM
    - XRD/XRR
    - Optical profilometer
    - SEM
High quality data: Unique Optical Reverse-Engineering.

The more measurements + Software ➔ higher accuracy ➔ more analysis information

- **Ellipsometry (SE) + Transmittant (T)**
  - Much more accurate $n, k$, thickness
  - Gradient along thickness direction

  - More accurate thickness, $n, k$,
  - More information: Gradient, carrier density, mobility ...

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Carrier Density and Mobility by Ellipsometry (SE) + Transmittance (T) + sheet resistance (R)
Software overcomes the knowledge barrier reduces the research time and cycles

- Optical prototype product research
  - No need for years training any more (no PHD degree is OK)
  - No need for extensive DOEs any more (cost significantly reduced)
    - As long as the model design results meet the spec, nearly 90% post deposition film can meet the spec
- Researchers can focus their research goal, reduce knowledge / process barrier.

Example of an optical coating spec

*US patent :US 2014/0272354 A1
Workflow: Fast Research Cycle

Combinatorial deposition
Stack
New materials

Metrology: Optical and Electrical, Thermal

Glass Substrate

New DOE based Model design

55 nm Si3N4
17.5nm AgTi
53nm Si3N4
Glass

New Model Design

Revers Engineering

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Unique quick screening/prototyping optical products

• How fast is fast?
• Is that possible to finish a patent alert or a publication in two weeks?
• Average less than 2 weeks for a patent alert?
Trends for More Innovations

**Industry trends**

- **Equipment:** Lower cost, Higher throughput
- **Software** Model & Design are more powerful/convenient
- **Expertise** and Database are more easily accessible

**Reduce Research Thresholds**

- Open Lab for Invention
- More ideas
- Small funding

**Attract More Brains**

- A prototype
  - Or test an idea

**More innovations**
A new path for more innovations

• Today this was a news: “Amateur astronomer catches first glimpses of birth of a supernova”
• Could optical materials research is common as amateur astronomers someday?
• The threshold for optical research is significantly reduced now,
  – **Anyone who has a dream of innovation, could spend his effort, could achieve some prototypes, patents, publications, by a new lab service.**
  – Tens of thousand $ is possible for a project
    o A family, rather than a company is possible for a research funding by a personal reason
    o A research director, without a complicated funding applications, could decide a small funding
• Affordable Lab ➔ more brains, ➔ better ideas, ➔ more innovations.
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Case study 1: Co-sputtering for new materials / Optical coating optimization development

- New materials $\text{Ag}_x \text{Ti}_y$ research and characterization

- Designing an energy saving product with the new materials
  - High performance product
  - Publication was done in 2 weeks

Published: G. Ding and T. Lu, 8th International Conference and Exhibition on Lasers, Optics & Photonics, Nov. 2017, USA
Case study 2: High transmittance energy saving window coating product development

- A publication was finished in less than 2 weeks.
- High transmittance low-E coating obtained, matches high transmittance low-E performance
  - Coated glass $T_{\text{vis}}$: 86%
  - Insulating Glass Units Performance:
    - $T_{\text{vis}}$: 79.0%
    - Light-to-Solar Gain: 1.51

Results published:
Zhou et al., 14th International Conference and Exhibition on Materials Science and Engineering, Nov. 2017, USA
Case 3 Trouble-shooting customer issues

• There is a color issue in a customer coating
• We did Optical Reverse Engineering which indicated that there was a metal migration into another layer by xx%.
• Research on a new barrier material
  – Software Designs a new coating stack
  – PVD deposition
• ➔ Resolve the color issue
Summary

• The future research trends on faster, cheaper, better solutions as the trends of Moore’s law.
• There will be a point in time when the research threshold is so low that attract more brains, with more ideas for more innovations.
• Labforinvention is such a Laboratory with a mission of better, faster cheaper solutions for thin film research.
• “Optical coating innovation is accessible, affordable, and open to everyone who want to have an innovation”, is closer to the reality.
• Thanks to our partner, Covalent Metrology, better, faster and cheaper data for every client
• Thanks for your attentions